10/PARTS

10/526997
DT01 Rec'd PCT/PTO 07 MAR 2005

TURBO-ROTARY, COMPOUND AND SOLO PROPULSION ENGINE AND THERMODYNAMIC CYCLE

FIELD OF THE INVENTION

This invention relates to energy systems and more particularly to componentry and thermodynamic cycle for enabling shaft work, propulsion drive, electric power source, jet propulsion and thermodynamic systems such as ventilation, cooling, heat, pressure or vacuum generating systems.

BACKGROUND OF THE INVENTION

Since the start of the industrial revolution, the reciprocating piston engine based on the Otto and Diesel cycles and, the gas turbine engine based on the Brayton cycle, have largely dominated the market. Despite this fact, for many years, patents on rotary combustion engines have claimed that rotary engines possess many advantages over reciprocating engines such as having high torque, fewer parts, lower weight and fewer reciprocating imbalance. Fundamental design characteristics of the present invention addresses the main problems related to rotary engines and bridges the mass flow and rotational speed gaps between reciprocating and gas turbine engines.

Avoiding Wear and Improving Sealing in a Vane Rotary Engine

One reason for the lack of industrial attention is that many rotary engines have been faced by serious wear and sealing deficiencies. The main cause of the wear is the centrifugal force generated during high speed rotation that forces the vanes to scrap the inner peripheral of the working chamber. This has been recently addressed by using hinged vane central retention mechanisms (USPTO 5,352,295, Chou Yi, October 4th, 1994 and PCT WO 02/31318, VADING Kjell, April 18th, 2002). In such configurations, the sliding vane is articulated through a cylindrical slideable guidance placed between the rotor and the vane. While correcting the wear problem, the number of moving parts has increased and hence, the system became more complex. At worst, each one of said parts increases the probability of engine failure

due to wear and fatigue. At best, the pressure sealing, lubrication and cooling capabilities of the vane mechanism deteriorates. In the present invention, the intermediary cylindrical slides are eliminated all together as the radially outer vane tips (86,109) are always in a natural contact with the housing inner peripheral (88,97). The basic reason for this natural contact is that the housing inner peripheral (88,97) is non-circular and has a cycloidal shape (Figure 6) that accommodates perfectly an eccentrically placed sliding vane of fixed length (16,37,50,63,87,100,119, 125). The easy machining and manufacturing technique disclosed in this invention, is based on the side enlargement of the largest fitting circle within the cycloid (Figure 6), and have not been mentioned by prior arts (USPTO 6,236,897, LEE and al.,May 22nd, 2001; USPTO 5,996,355, Jirnov and al., December 7th, 1999, USPTO 4,422,419, UMEDA, December 27th, 1983). The said geometry (Figure 6), given in the detailed description and the related claims of the invention below, has good sealing at all sliding vane position angles. Wear contacts generated by the sliding vane tips (86,109) against the housing inner peripheral (88) are eliminated by a pivot axle vane retention mechanism (54, 55, 61, 62, 81, 82, 104, 105) centrally placed within the rotor.

Rotary Engines with Sliding Vane Slicing Through Rotor

Instead of having hinged vanes, some of the prior arts do use sliding vanes slicing through the rotor (USPTO 4,414,938, UMEDA Soei, November 15th, 1983 and USPTO 4,422,419, UMEDA Soei, December 27th, 1983; USPTO 5,596,963, LAI, Jui, H., January 28th 1997). In these arts, a plurality of spring-loaded vanes are used against the housing wall to achieve air-tightness. Therefore, they fundamentally differ from the springless single “all-through solid” vane mechanism of the present invention. Furthermore, above-mentioned prior arts do not have any central vane retention mechanism (138,139,150) that would prevent the related wear problem. Moreover, only a portion of the entire inner peripheral of the housing is elliptic. Another patent, related to rotary heat engine with ‘all-through solid’ vane (USPTO 5,511,525, JIRNOV and al., April 30th, 1996), uses at least two mutually perpendicular vanes with radially extending guide. The plural use of vanes within one compressor housing substantially reduces the pressure ratio. This leads to a

reduction of the rotary component efficiency and also increase the system complexity as more stage is required. Furthermore, the vane guide path mechanism described in this prior art is an additional cause for increased friction wear.

Rotary Engines with Separate Compression and Expansion Chambers

There are many rotary engine patents which provide separate compression, combustion and expansion chambers (PCT WO 02/31318, VADING Kjell, April 18th, 2002; PCT WO 99/041141, O'BRIEN Kevin, January 28th 1999; USPTO 5,596,963, LAI, Jui, H., January 28th 1997; USPTO 5,335,497, MACOMBER Bennie D., August 9th, 1994; USPTO 5,352,295, YI Chou, October 4th 1994; USPTO 5,235,945, TESTEA Goerge, August 17th, 1993). Actually, almost all rotary vane type engines produce very high torque because the combusted gas expands right against the hot section vane (37,63,100,119), which is the arm length of the generated torque. Therefore, not only is the crankshaft unnecessary, but when comparing engines of equal volumes, the power leverage on the drive shaft of a rotary engine is greater than that of a corresponding reciprocating engine. However, here too, there is room for improvement; the present invention overcomes the drawbacks and limitations of todays power and refrigeration cycles by proposing and implementing new high efficiency thermodynamic cycles (151abceh, 151abcdfh, 151abcgh)

Rotary Engine with Improved Thermodynamic Cycle

The present invention combines the advantages of Otto and Diesel cycles at intake, compression and combustion phases of the thermodynamic cycle by limiting the peak combustion temperature. The present invention also claims an expanded power stroke that greatly improves power extraction and efficiency. With a proper thermodynamic and geometrical match of the compressor and turbine working chambers, it is shown that the expansion process can be improved and lower exhaust pressure and temperature levels can be achieved. A search of the prior art did not disclose any rotary engine patent with separate compression and expansion chambers that considers and provides an expansion process that would take the combusted products further down to ambient pressure levels. The overlook of such thermodynamic cycle improvement is a major source of wasted energy that ultimately

translates in engine fuel inefficiency. Accordingly, the present invention provides proper sizing of the compression and expansion chambers, the rotors, and the vanes so as to achieve optimum compression (151ab), combustion (151bce, 151bcdf, 151bcg) and expansion (151eh, 151fh, 151gh).

OBJECT OF THE INVENTION

One of the objects of this invention, is to increase the thermal efficiency above levels reached by today's heat engines. This is achieved by implementing a longer power extraction phase (151eh, 151fh, 151gh) and by realising high compression ratios with less shaft power input, by processing the fluid through a smooth crescent shape constriction (72 and 49 and 53). Another object of the present invention is to decrease the wear. Wear is minimised through the incorporation of the pivot axle vane retention mechanism (138,139,150) and by providing an efficient oil lubrication. The operational and maintenance costs are also minimised, as maximum peak temperature is limited. All together, the present invention discloses an efficient, powerful, compact, simple and reliable heat engine.

For the compound engine configuration of the instant invention, rotary components and gas turbine engine components have been matched with each other. The objective is to combine the high efficiency and "no-stall" characteristics of internal combustion engines with the high mass flow, smaller size and lighter weight characteristics of the gas turbine engines. Another objective is to eliminate the long, heavy and cumbersome concentric shafts and reduction gears that are present in today's turbofan, turboprops and turbojet engines. By simplifying the mechanical links and by integrating low mass flow rotary components, the implementation of high efficiency reheat and intercooling systems have become extremely feasible.

SUMMARY OF THE INVENTION

The solo configuration (Figures 1,2,3,4) of the invention relates to a rotary vane type machine comprising a compressor (10,19;46,48) and a turbine (36,43;57,59) housing, each having a crescent shape cavity. Each of these housing is receiving an eccentrically placed rotor (4,11,89,96,130,117) equipped by a radially movable single

sliding vane (50,63) arranged in the rotor. The rotor receives a centrally placed pivot axle vane retention mechanism, which is comprised of a pin (139) and a pivot axle (150). The pin head fits into the vane centre socket. Both ends (86,109) of the sliding vane (87,100,119,125) are extending radially outward and are in contact with the cycloidal inner surface of the housing peripheral (88,97) at all rotational angles. Within each housing, depending on the rotational position of the sliding vanes, forms a plurality of working chambers (49, 53, 60, 66, 72) each of the said chambers, delimited by the inner peripheral surface of the housing (48, 59), the outer peripheral surface of the rotor (90, 98) and the side surface of the vane (16, 37). With such configuration, the solo use of the turbo-rotary engine of the invention overcomes the limitations of conventional internal combustion engines and enables significant improvement in power, torque and efficiency. The cycloidal housing inner peripheral eliminates any use of telescoping, articulated hinged vane mechanism and gives the engine of the invention a simple and naturally balanced configuration.

For high mass flow rate, the present invention (Figures 8,9,10) extends the efficient but narrow operating range of the gas turbine engine by mechanically decoupling and eliminating the long shaft drive between the expander (turbine) and the turbo-compressor. Each said fan (153,155) and compressor group (158,161,182,197) is allowed to be driven at its own speed, by its own rotary turbine (154,156,157,162, 181, 196) wherein, amounts of combustion fuel and air is delivered is dictated by the instantaneous compressor load requirements. Turbines (170, 171, 178, 191) drives rotary compressors (164,166,168,179,195,190) that pumps high pressure fluid to respective rotary turbines. Therefore the present invention overcomes some of the off-design limitations of conventional gas turbine engines. Because of their low mass flow rate requirements, it also becomes extremely cheap and useful to equip the system with intercoolers (193) and reheat (198) systems. Other features, advantages, and applications of the invention will be apparent from the following descriptions, the accompanying figures, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated hereinafter through preferred and alternative embodiments wherein:

Figure 1, is a schematic isometric view of a rotary engine where compressor (10) and turbine (43) housings are arranged in tandem. The gas transfer from the compressor to the turbine is sequenced by a rotor synchronised (24, 25, 26, 27, 8, 7, 6) cyclo-valve. Combustion occurs within the turbine expansion chamber.

Figure 2, is a schematic top view of the rotary engine of Figure 1, sectioned at mid height of the turbine housing. Isometric view of the cyclo-valve (69, 70, 71) is added.

Figure 3, is a schematic isometric view of a rotary engine where compressor and turbine housings are arranged in tandem. The gas is transferred from the compressor to the turbine through an intermediary cyclo-combustion chamber (74) synchronised with the rotational speed of the compressor and the turbine. Expansion occurs within the turbine chamber (103).

Figure 4, is a schematic isometric view of a rotary engine where compressor (122) and turbine (121) housings are arranged back-to-back thereof, the compressor rotor (126) is coaxial with the turbine rotor (117). Combustion occurs externally within a cyclo chamber (114) and expansion occurs within the turbine.

Figure 5, is an exploded isometric view of rotor (135), sliding vane, sealing elements (131, 137, 140, 145, 146, 148), under seal springs (141, 143, 144, 147, 149), vane retention pivot axle (150) and pin (138,139).

Figure 6, geometry of the cycloid machined by enlarging by '2δ', the largest circle of diameter 'L' that fits the housing peripheral (88,97)

Figure 7, high efficiency, high power, low peak temperature new thermodynamic cycles (151abceh, 151abcdfh, 151abcgh) pertaining to the invention.

Figure 8, turbo-rotary-fan compound engine

Figure 9, turbo-rotary-prop compound engine

Figure 10, turbo-rotary compound engine for helicopter or power applications.

DETAILED DESCRIPTION OF THE INVENTION

The embodiments of the invention for which an exclusive privilege or property is claimed are described as follows:

Figure 1 and Figure 2 depict a preferred embodiment of the internal combustion rotary engine where combustion occurs within the turbine chamber (66). Figure 3 depicts a different preferred embodiment of an external combustion (74, 92) rotary engine where combustion starts in a chamber (72) prior to entry within the turbine expansion chamber (103). The rotary combustion engine casing (14, 21, 35, 44) comprises at least one rotary compressor unit wherein, said unit has inner (19, 48) and outer (46) housings. The engine casing also comprises at least one rotary turbine unit wherein, said unit has inner (59) and outer (57) housings. Said housings are surrounded by a liquid cooled jacket (18, 41, 45). For example, water may be used as coolant. The housings have each, a circularly cylindrical (3, 13) rotor (12,128), rotatably and eccentrically mounted. The said rotary engine breathes through the intake (20) and exhaust (34,116) ports. The compressor rotor outer boundary (83,126) and turbine rotor outer boundary (98) are sealingly (86,101) mounted (90, 95) tangent to the chamber inner peripherals (88, 97). Accordingly, the respective rotor outer boundary and the chamber inner peripheral are osculating at their common tangency plane (90, 95). As shown in more detail in Figure 5, each of the said rotors (135) have an internal vane groove (1) and many seal slots (118, 129, 134, 136) and oil cooling holes (2, 130, 133).

The sliding vane also carries many slots (14, 38, 40, 52, 64, 84, 124, 120) that accommodates seals. The radially outer vane tips (86,101,109) are always in a natural contact with the housing inner peripheral (88, 97). This is because the housing inner peripheral is non-circular and has a cycloidal shape that accommodates well an eccentrically placed sliding vane of fixed length. As seen from Figure 6, The cycloidal peripheral (88, 97) is a unique shape, mainly depending on 4 parameters: the radial offset distance between the rotor center 'o' and the center of the chamber 'c', the sliding vane length 'L', the seal height (145) and the seal spring (144). The dynamic and thermal loading behaviour of the seal spring under rotation and the circumferential temperature differences may slightly alter the cycloidal shape.

The machining and the manufacturing of the cycloidal shape of the present invention is achieved by enlarging by a distance 'δ', both opposite sides of the largest circle of diameter 'L' in such a way that, as the rotor rotates around its eccentrically placed axis over a range $0° \leq \theta \leq 180°$, the radially outer tips of the springless vane, define the said cycloidal shape of the housing inner peripheral. The exact coordinates of such cycloidal shape is used in the precision manufacturing of the housing inner peripheral using modern manufacturing techniques, including using CNC techniques

The pivot axle vane retention mechanism (54, 55; 61, 62; 81, 82; 104, 105) is a unique mechanism where the pivot is always tangent to the rotor central cavity (80). The pivot is a tubing (150) and retains the pin (139) which is embedded by one end into the sliding vane center socket (Figure 5). The pivot rotates at twice the speed of the pin and the vane. Roller, gear (not shown) or sliding head (55,81) of said pivot axle is engaging the cylindrical rotor inner peripheral (80) to guide the vane through its eccentric rotating and reciprocating sliding motion.

Intake chamber (53) is receiving the fluid from intake port (20), said fluid is either air, or any other working gas, or any other liquid-gas mixture. Said fluid, is compressed by the compressor rotor (12, 89) and the single rigid sliding vane (50, 87) which is sealingly (86) and movably mounted within the rotor groove. The sliding vane is contoured (127) to fit the said groove. By placing the sliding vane (16, 50, 87) within the compressor housing, a plurality of working chambers (72, 49, 53 and 106, 107, 108) are sequentially created within the crescent shaped cavity, delimited by the compressor housing inner peripheral (88) and the rotor outer surface (83). When compared with gas turbine engine compressor, the rotary compression work is at least 2-15% more efficient as the fluid is sealed within the closed control volume (49, 107). The compression work within the crescent shape is smooth and gradual and therefore the compression is nearly isentropic. As a result of the rotation of the rotor, a periodic sequence of compressed fluid is delivered to the exhaust port (56, 76) of the compressor housing. The rotary combustion engine compressor casing is sealed at its opposite ends by bolted (9) plates (10). One of the compressor end plates is apertured at its centerline to allow for the drive shaft.

Figures 1, 2 and 3 depict preferred embodiments where compressor and turbine housings are arranged in tandem. For such configurations, power and torque transfer and synchronization of compressor and turbine rotors (12, 3) and valve rotation (67, 69) are achieved with drive shafts (31, 8, 6, 69), gears (33, 28, 26, 24) or other transmission mechanisms (7, 25, 30), and bearings (not shown) supported by the engine casing (32, 21, 22, 23, 27). For the preferred embodiment depicted in Figure 4, power transfer between the turbine and the compressor is much simpler, as the compressor (129) and turbine (117) rotors are directly coupled to the drive shaft (110). The shaft is journalled in bearings supported by the engine casing (121,122). The back-to-back compressor and turbine configuration is compact and lightweight as no gear, pulley and auxiliary power and torque transfer equipment is used. A fluid transfer passage (114) connects the exhaust port (76) of the compressor and the intake port (73) of the turbine. In the external combustion engine depicted in Figure 3, the said transfer passage includes a combustion chamber (74, 92) which is periodically pressurised by gas flow from the compressor exhaust port. Downstream of said compressor exhaust port there is at least one check valve and/or at least one cyclo-valve (67, 68, 93) , operating between open and closed positions, in timed sequence with the passage of the turbine sliding vane (100). The closed position (94) of the said valve prevents gas flow from the combustion chamber into the compressor. The cyclo-valve comprises a tubing (70) having inlet and exhaust ports (71) and a rotatably and sealingly mounted slotted cylinder (69) within the said tubing.

Two firing cycles occur per rotor revolution. As one firing takes place (91), new cycles (92, 107, 108) are preceding the present firing and at least one old cycle (60, 99) is terminating thereof, a smooth operation is assured. The rotary turbine unit is similar to the compressor unit but its size differs. Working chambers (60, 66, 103, 99), belonging to the turbine are delimited by the housing inner peripheral (97), the rotor outer surface (98) and the side surface of the sliding vane (37). For Figure 3, the combustion working chamber (74) and the expansion chamber (103) are separate but linked. Thus, the turbine housing is allowed to run at a reduced temperature. A periodic sequence of expanded fluid is delivered from the exhaust port (34) with each rotation of the turbine rotor in response to high pressure and temperature gas

expansion in the said turbine. The exhaust gas pressure is lowered to about local ambient pressure values to allow maximum shaft work extraction and increase in thermal efficiency. As shown in Figure 7, the maximum volume of the turbine expansion chamber (66) is sized such that the combusted gas pressure (151e, 151f, 151g) is expanded to local ambient pressure (151h). The height of the turbine inner housing (36) and the turbine rotor (117) is sized in such a way that, the pressure of the gas, as it is being transferred from the compressor chamber (72) is maintained to about a constant high value (151b). The turbine casing (35) is sealed at its opposite ends by bolted (42) plates (43). One of the said plates is apertured at its centerline, to accommodate the drive shaft (31) protruding therefrom.

A fuel or a fuel/atomiser mixture (75) is supplied to said combustion chamber (74, 66) using commercially available fuel injection or fuel aspiration means. The fuel/oxidizer mixture is ignited using commercially available spark (91) or pressure ignition means. For each 360 degrees of rotation of said compressor rotor, there are two complete and consecutive cycles of intake (108, 151a), compression (92, 151ab), combustion (74, 151bce; 151bcdf; 151bcg), power (66,103, 151eh; 151fh; 151gh) and exhaust (60, 99, 151h) phases.

The thermodynamic cycle associated with the intake, compression, combustion, expansion and exhaust phases of the rotary engine contains innovations when compared to the Otto, Brayton, Diesel or more recent increased expansion cycles proposed in prior arts (PCT WO 02/090738, DUNCAN, Ronnie J., November 14th, 2002; USPTO 5,341,771, RILEY, Michael B., August 30th, 1994). At intake, compression and combustion phases, the present invention combines the advantages of Otto and Diesel thermodynamic cycles. It is well known that for a given compression ratio, the ideal Otto cycle currently provides the most efficient combustion/expansion process since it combines high peak temperature during the isochoric (constant volume) heat addition, while still keeping an acceptable mean chamber temperature. However, high peak combustion temperatures can cause auto-ignition of a portion of fuel-air mixture, resulting in engine knocks. Diesel is an improvement of the Otto cycle as it provides higher useful compression ratios and isobaric (constant pressure) heat addition and do not have knock problem as air

alone is present during the compression process. The high compression ratio makes Diesel engines more fuel-efficient but for this same reason, they also become much heavier. Compared to the Otto cycle, Diesel cycle also delivers less power for the same displacement. For the compression and combustion phases of the cycle, the ideal would be to follow a limited combustion pressure cycle that would first use a combined isochoric heat addition followed by isobaric and/or isothermal heat additions. As mentioned in a prior art, (USPTO, 5,566,650, KRUSE, Douglas C., October 22nd, 1996) such hybrid engine process has been developed (Texaco TCCS, Ford PROCO, Ricardo, MAN-FM and KHD-AD) but they have been proven impractical. The rotary engine of the present invention naturally follows the above-described limited peak cycle (151bce; 151bcdf; 151bcg) multi-step (isochoric, isobaric and/or isothermal) combustion phases.

By limiting the peak combustion pressures, the present invention also provides an expanded power stroke that improves power extraction (151eh; 151fh; 151gh). A search of the prior art did not disclose any patents that considers a thermodynamic heat engine cycle, whether it be reciprocating or rotary, that jointly proposes a limited peak combustion pressure and an expansion phase where the pressure exhausts to about ambient pressure.

One of the drawbacks of the current gas turbine engines are their highly sensitive stall characteristics always placed close to the high performance region. Furthermore, shaft and aero-thermodynamic coupling and feedback loop between the compressor and the turbine, only allows a narrow, high efficiency operational band. The present invention provides a practical and effective means of adding higher degrees of freedom to the gas turbine engines by eliminating the shaft coupling between fans, compressors and turbines. The compound engine (Figures 8, 9, 10) of the present invention combines the efficiency of the heat engines with the compactness, lightweight and high power characteristics of gas turbine engines. Heat engines can produce kilowatts of power at high power densities and efficiencies but they are heavy and of relatively large sizes. After 50MW, most of thermodynamic scaling and cost considerations have favoured large size gas turbine engines. 100 MW gas turbine combined cycle power plant costs about 500 USD per kW, whereas

10 MW power plant costs 750 USD per kW and 1 MW power plant costs 1000 USD per kW. For small power range (0.1-10 MW), internal combustion engine becomes highly competitive despite their size, weight and high maintenance cost. The present invention overcomes the limitations of both small gas turbine engines and large internal combustion engines and meets the modularity, high efficiency, mobility weight and cost requirements of today's modern power and propulsion applications.

The invention provides a preferred embodiment of a high mass flow propulsion device. This is achieved by a mechanical coupling (162, 165, 167) of the rotary engine components with conventional gas turbine engine components. The turbo-rotary compound engines (Figures 8, 9, 10) of the invention, eliminates conventional long and heavy concentric shafts and disclose a novel configuration where conventional rotational wing (186), fans (153, 155) compressors (158, 161, 182, 197) and turbines (170, 171, 178, 191) are only aero-thermodynamically coupled with each other. In this invention, rotary turbines (154, 156, 157, 163, 181, 188, 196) drive said rotational wing, fans and compressors. Conversely, said conventional turbines drive single or a plurality of rotary compressors (164, 166, 168, 179, 195, 190). Rotary compressors supply compressed fluid via flexible high-pressure connections (172, 187, 189, 194). Relatively low mass flow will move through such connection as both rotary compressors and turbines are partial admission machines. Low mass flow also favours the efficient use of intercooler (193) and reheat (198) systems, giving a further boost to thermal efficiency. The compound engine of the invention combines the thermal efficiency of the rotary internal engine cycle and the high mass flow, compact size and lightweight of the gas turbine engines. Such a compound cycle propulsion engine may comprise propellers, conventional fans, contra-rotating fans, hub-turbine driven fans (177, 176), contra-rotating hub-turbine driven fans (175, 174), axial and/or centrifugal compressor stages, combustion chambers (173), axial and/or centrifugal turbine stages, rotary compressors and turbines, intercoolers and reheaters. The current design is versatile and simple, therefore well adapted to turboprop, turbofan, marine and land based power production and refrigeration applications. The subject design can also be applied to geothermal power plants.

As is demonstrated by the breath of this description, the range of application for the compound and solo use of the turbo-rotary engine provided by the invention is truly vast. In particular, the scope of the present invention includes hybrid turbo-rotary engines where conventional axial and/or radial turbines drive both conventional axial and/or centrifugal compressors and rotary compressors. Also included in the present invention, hybrid applications where conventional axial and/or centrifugal compressors are driven by both conventional axial and/or radial turbines and rotary turbines. While the description cannot address each and every application, it is intended to indicate the extensive capabilities contemplated by the invention.

CLAIMS

The embodiments of the invention for which an exclusive privilege or property is claimed, are defined as follows:

1. A sliding vane rotary combustion engine, which is characterised having at least one rotary compressor and at least one rotary turbine, an ignition and a combustion system.

2. A rotary compressor of claim 1, having a circularly cylindrical rotor, rotatably and eccentrically mounted within the compressor housing having intake and exhaust ports. Said rotor cylindrical outer boundary, being sealingly mounted tangent to the chamber inner peripheral such that the rotor outer boundary and the chamber inner peripheral are forming osculating planes. Said rotor having an internal vane groove, aligned along its diametrical axis.

3. The compressor rotor of claim 2, receiving a single rigid sliding vane, sealingly and movably mounted within the rotor groove. Both tips of the sliding vane are extending radially outward from the said rotor vane groove and are sealingly contacting the cycloidal inner surface of the housing peripheral. Said sliding vane has a radial reciprocating movement guided by the groove in the rotor in such a way that, as the rotor rotates, sealing means at both tips of the vane are in sealing contact with the cycloidal inner surface of the housing peripheral at all rotational angle positions of the said rotor.

4. Sliding vane of claim 3, thus defining a plurality of working chambers placed sequentially within the crescent shaped cavity bounded by the compressor housing inner peripheral and the rotor outer surface thereof, said working chambers are delimited by the housing inner peripheral, the rotor outer surface and the side surface of the sliding vanes. A plurality of sealing means fixed to each radially outer tips of the said sliding vane for pressure sealing the various working chambers of the compressor from each other. Said working chambers being the intake chamber receiving the fluid, said fluid being in gas, in liquid or in any mixture form; the fluid confinement chamber and the fluid compression chamber. As a result of the rotation

of the rotor, a periodic sequence of compressed fluid is delivered to the exhaust port of the compressor housing.

5. The compressor rotor of claim 2, has a rotor axis which receives a pivot axle vane retention mechanism which is comprised of a pin and an pivot axle, thereof the pin head fits into the vane center socket. The remaining length of the rotatable pin is mounted within an eccentrically drilled hole of the pivot axle. Roller, gear or sliding head of said pivot axle is engaging the cylindrical rotor inner peripheral to guide the vane through its eccentric rotating and reciprocating sliding motion.

6. A rotary combustion engine of claim 1, wherein said compressor casing is sealed at its opposite ends by plates. Wherein said plates are apertured at their center line, said aperture having bearing, sealing and lubricating means therein to support, seal and lubricate the ends of said drive shaft protruding therefrom.

7. A rotary turbine of claim 1, having a circularly cylindrical rotor, rotatably and eccentrically mounted within the turbine housing having intake and exhaust ports. Said rotor cylindrical outer boundary, being sealingly mounted tangent to the chamber inner peripheral such that the rotor outer boundary and the chamber inner peripheral are forming osculating planes. Said rotor having an internal vane groove, aligned along its diametrical axis.

8. The turbine rotor of claim 7, receiving a single rigid sliding vane, sealingly and movably mounted within the rotor groove. Both tips of the sliding vane are extending radially outward from the said rotor vane groove and are sealingly contacting the cycloidal inner surface of the housing peripheral. Said sliding vane has a radial reciprocating movement guided by the groove in the rotor in such a way that, as the rotor rotates, sealing means at both radially outer tips of the vane are in sealing contact with the cycloidal inner surface of the housing peripheral at all rotational angle positions of the said rotor.

9. Sliding vane of claim 7, thus defining a plurality of working chambers placed sequentially within the crescent shaped cavity bounded by the turbine housing inner peripheral and the rotor outer surface thereof, said working chambers are delimited

by the housing inner peripheral, the rotor outer surface and the side surface of the sliding vanes. A plurality of sealing means fixed to each tips of the said sliding vane for pressure and temperature sealing the various working chambers of the turbine from each other. Said working chambers being the combustion chamber; the expansion chamber and, the exhaust chamber. A periodic sequence of expanded fluid is delivered from the exhaust port of the turbine housing with rotation of the turbine rotor in response to high pressure and temperature gas expansion in the said turbine.

10. The rotary turbine housing of claim 7, having the cycloidal inner housing peripheral, the rotor outer diameter and the sliding vane thickness sized in such a way that burned gas pressure is lowered to about local ambient pressure values when the expansion chamber volume reaches its maximum.

11. The rotary turbine of claim 7 and its components sized according to claim 10, having the cycloidal inner housing and the rotor height sized in such a way that, the pressure of the gas, as it is being transferred from the compressor chamber is maintained to about a fairly constant value.

12. The turbine rotor of claim 7, has a rotor axis which receives a pivot axle vane retention mechanism which is comprised of a pin and an pivot axle, thereof the pin head fits into the vane center socket. The remaining length of the rotatable pin is mounted within an eccentrically drilled hole of the pivot axle. Roller, gear or sliding head of said pivot axle is engaging the cylindrical rotor inner peripheral to guide the vane through its eccentric rotating and reciprocating sliding motion.

13. A rotary combustion engine of claim 1, wherein said turbine casing is sealed at its opposite ends by plates. Wherein at least one of the said plates are apertured at their center line, said aperture having bearing, sealing and lubricating means therein to support, seal and lubricate the ends of said drive shaft protruding therefrom.

14. A drive shaft of claim 1, journalled in bearings supported by the engine casing and coupled to the compressor and turbine rotors for power and torque transfer and for synchronized rotation thereof; a plurality of sealing means for sealing the said

drive shaft in the said rotary engine casing. Wherein the compressor and the output shaft are powered by the combusted gas expanding through the turbine. Said compressor housing adjacent to turbine housing and, said compressor rotor coaxial with said turbine rotor.

15. A drive shaft, gear or other transmission mechanisms of claim 1, journalled in bearings supported by the engine casing and coupling the compressor and turbine rotors for power and torque transfer and for synchronized rotation thereof; a plurality of sealing means for sealing the said drive shaft in the said rotary engine casing. Wherein the compressor and the output shaft are powered by the combusted gas expanding through the turbine. Said compressing and turbine housings arranged in tandem and, said compressor rotor coupled with said turbine rotor through a shaft, gear or other power and torque transmission mechanisms.

16. A fluid transfer passage of engine of claim 1, connected between the exhaust port of the compressor and the intake port of the turbine. The transfer passage including a combustion chamber, said combustion chamber being periodically pressurised by gas flow from the compressor exhaust port. Downstream of said compressor exhaust port comprises at least one check valve, and/or at least a rotary vane combustion chamber valve, and/or at least one cyclo-valve, all said valves operating between open and closed positions, in timed sequence with the passage of the turbine sliding vane in front of the intake port of the turbine housing. The closed position preventing gas flow from the combustion chamber into the compressor. Said cyclo-valve comprises a tubing, having inlet and exhaust ports and a rotatably and sealingly mounted slotted cylinder within the said tubing.

17. A fluid transfer passage of engine of claim 1, connected between the exhaust port of the compressor and the intake port of the turbine. The transfer passage comprises at least one check valve and/or at least one cyclo-valve, all said valves operating between open and closed positions, in timed sequence with the passage of the turbine sliding vane in front of the intake port of the turbine housing. The closed position preventing gas flow from the turbine combustion and expansion chamber into the compressor. Said cyclo-valve comprises a tubing, having inlet and exhaust ports and a rotatably and sealingly mounted slotted cylinder within the said tubing.

18. A fuel or a fuel/atomiser mixture supply means penetrating the said rotary engine casing and connected to said combustion chamber, wherein said fuel or fuel/atomiser mixture supply means comprise one of either a fuel injection means or a fuel aspiration means; a fuel/oxidizer mixture ignition means penetrating the said engine casing and connected to said combustion chamber, wherein said fuel/oxidiser ignition means comprise one of either a spark ignition means or a pressure ignition means; means for isolating the combustion products in the combustion chamber and in the expansion chamber from the compression chamber and the exhaust port during expansion thereof; an exhaust gas removal means penetrating said rotary engine casing and connected to said turbine exhaust port.

19. A heat of combustion removal means penetrating said rotary engine of claim 1, casing and surrounding said rotary engine and said connected to an external coolant recirculating means and external heat radiation means.

20. A plurality of lubrication means for lubricating all of the moving parts of the rotary engine of claim 1; and wherein, for each 360 degrees of rotation of said compressor and turbine rotors, there are two complete and consecutive cycles of intake, compression, combustion, power and exhaust phases.

21. A method of machining and manufacturing the cycloidal shape of the housing inner peripheral of said compressor and of said turbine of claim 1, wherein the corresponding cycloidal shape is obtained from the largest circle that fits the said inner peripheral and by enlarging the said circle in such a way that, as the rotor rotates around its eccentrically placed axis over a range $0° \leq \theta \leq 180°$, the radially outer tips of the springless vane of claim 3 and 8, define the said cycloidal shape of the housing inner peripheral. The exact coordinates of such cycloidal shape being implemented as described in this claim, in the precision manufacturing of the housing inner peripheral of said compressor and of said turbine of claim 1, using modern manufacturing techniques, including using CNC techniques.

22. A method for a rotary combustion engine of claim 1, said engine includes an intake, a compressor, a combustor, a turbine, an exhaust and having a thermodynamic cycle.

23. The thermodynamic cycle of claim 22; wherein fluid is introduced during the intake phase, at pressures about ambient pressure.

24. The thermodynamic cycle of claim 22; wherein fluid is introduced during the intake phase at pressures greater than ambient pressure.

25. The thermodynamic cycle of claim 22, wherein the intake phase, described either in claims 23 or 24, is followed by a substantially isentropic compression process.

26. The thermodynamic cycle of claim 22, wherein the compression process of claim 25 is followed by the heat input phase comprised of a substantially constant volume combustion process, subsequently followed by a substantially constant pressure combustion process.

27. The thermodynamic cycle of claim 22, wherein the compression process of claim 25 is followed by the heat input phase comprised of a substantially constant volume combustion process, subsequently followed by a substantially constant pressure combustion process, which is then followed by a substantially constant temperature combustion process.

28. The thermodynamic cycle of claim 22, wherein the compression process of claim 25 is followed by the heat input phase comprised of a substantially constant volume combustion process, subsequently followed by a substantially constant temperature combustion process.

29. The thermodynamic cycle of claim 22, wherein the heat input phase, described either in claims 26, 27 or 28, is followed by a substantially isentropic heat power delivery and expansion process, said process having an exhaust phase equal to ambient pressure.

30. The thermodynamic cycle of claim 22, wherein the heat input phase, described either in claims 26, 27 or 28, is followed by a substantially isentropic heat power delivery and expansion process, said process having an exhaust phase greater than ambient pressure.

31. A compound propulsion cycle engine which comprises single or a plurality of rotating wings, propellers, contra-rotating propellers, fans, contra-rotating fans, hub-turbine driven fans, axial compressor stage rows, centrifugal compressor stage rows, combustion chambers, axial turbine stage rows, radial turbine stage rows, rotary compressors, rotary turbines, reheat systems, intercooler systems.

32. A single or a plurality of rotating wings, propellers, contra-rotating propellers, fans, contra-rotating fans, hub-turbine driven fans, axial compressor stage rows, centrifugal compressor stage rows of claim 31, driven by rotary turbine of claim 1.

33. A single or a plurality of rotating wings, propellers, contra-rotating propellers, fans, contra-rotating fans, hub-turbine driven fans, axial compressor stage rows, centrifugal compressor stage rows of claim 31, simultaneously driven by rotary turbine of claim 1 and conventional axial and/or radial turbines.

34. A single or a plurality of rotating wings, propellers, contra-rotating propellers, fans, contra-rotating fans, hub-turbine driven fans, axial compressor stage rows, centrifugal compressor stage rows of claim 31, simultaneously driven by rotary or piston type internal or external combustion engines and axial and/or radial turbines.

35. A single or a plurality of axial and/or centrifugal turbine stage rows of claim 31, driving a single or a plurality of rotary compressors of claim 1.

36. A single or a plurality of axial and/or centrifugal turbine stage rows of claim 31, simultaneously driving a single or a plurality of rotary compressors of claim 1 and one or a plurality of the following comoponents: rotating wings, propellers, contra-rotating propellers, fans, contra-rotating fans, hub-turbine driven fans, axial compressor stage rows, centrifugal compressor stage rows.

37. Compound turbo rotary engine of claim 31, comprising said single or a plurality of rotary compressor supplying compressed fluid to said single or a plurality of rotary turbines. A single or a plurality of fluid transfer passages connected between the exhaust port of the rotary compressor and the intake port of the rotary turbine. Said transfer passage comprises at least one check valve and/or at least one cyclo-valve. Said fluid transfer passages may incorporate reheat systems upstream of rotary

engine combustion chamber inlet ports and/or intercooler systems upstream of rotary compressor inlet ports.

38. A single or a plurality of hub-turbine driven propeller of claim 31. Said hub-turbine driven propeller, comprising a circumferentially extending row of radially extending turbine blades and a circumferentially extending rows of radially extending fan or propeller blades thereof, concentrically disposed about and extending radially outwardly from the radial outer ends of said turbine blades. Said hub-turbine to receive the combusted product efflux from the said gas turbine combustor and to produce shaft power.

Abstract

TURBO-ROTARY, COMPOUND AND SOLO PROPULSION ENGINE AND THERMODYNAMIC CYCLE

For low mass flow, the solo use of the turbo-rotary engine overcomes the limitations of conventional internal combustion engines and enable significant improvement in power, torque and efficiency. The solo configurations (Figure 1, 2, 3, 4) of the invention comprise compressor (48) and turbine housings (59), each housing receiving an eccentrically placed rotor (135), equiped by a single sliding vane (50, 63). Contact wear of the sliding vane tips (86, 109) with the chamber non-circular cycloidal peripheral (88, 97), is eliminated by a pivot axle vane retention mechanism (139, 150).

For high mass flow rate, a compound configuration (Figures 8, 9, 10) of rotary compressors and turbines with conventional gas turbine engine components, allows an improvement in efficiency and performance. Conventional long and heavy concentric main shafts are eliminated. In this invention, rotary turbines drive compressors (158), fans (153), propellers and rotary wings (186). In return, the conventional turbines (171) drives a plurality of rotary compressors (164, 166, 168). The compound engine of the invention combines the thermal efficiency of the rotary internal engine cycle (151) and the high mass flow, high power, compact size and light weight of the gas turbine engines.

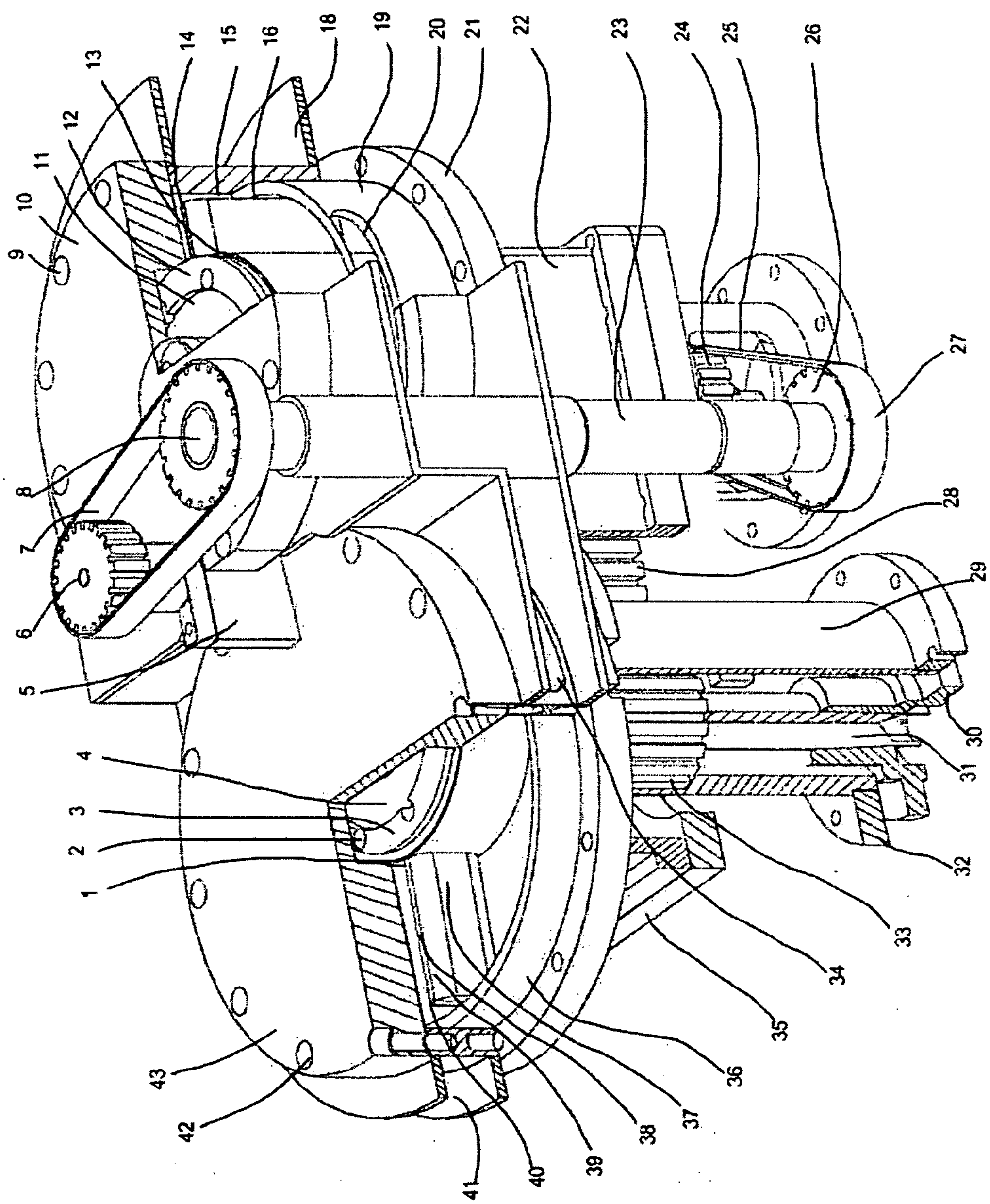

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43

FIGURE 1

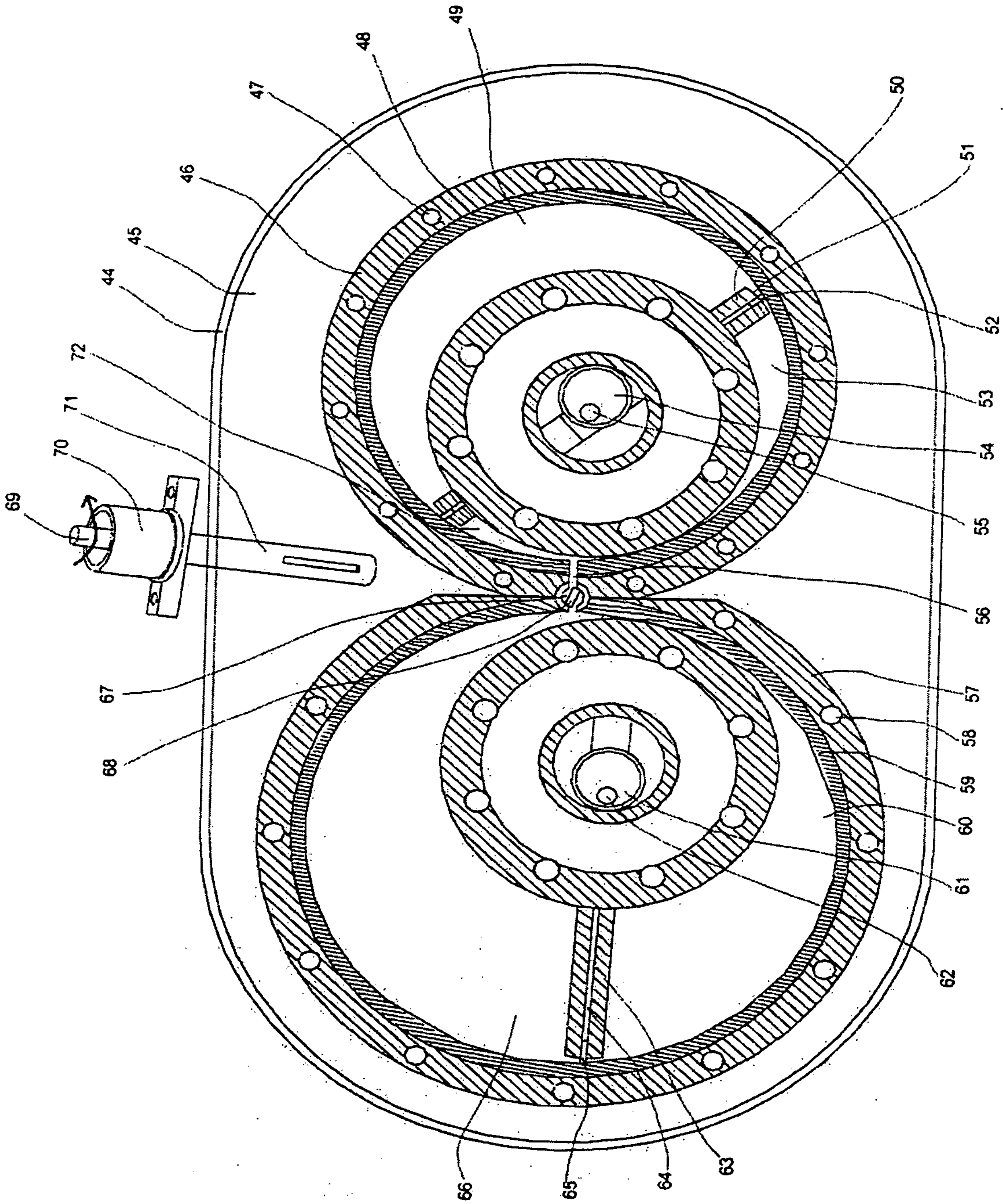

44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72

FIGURE 2

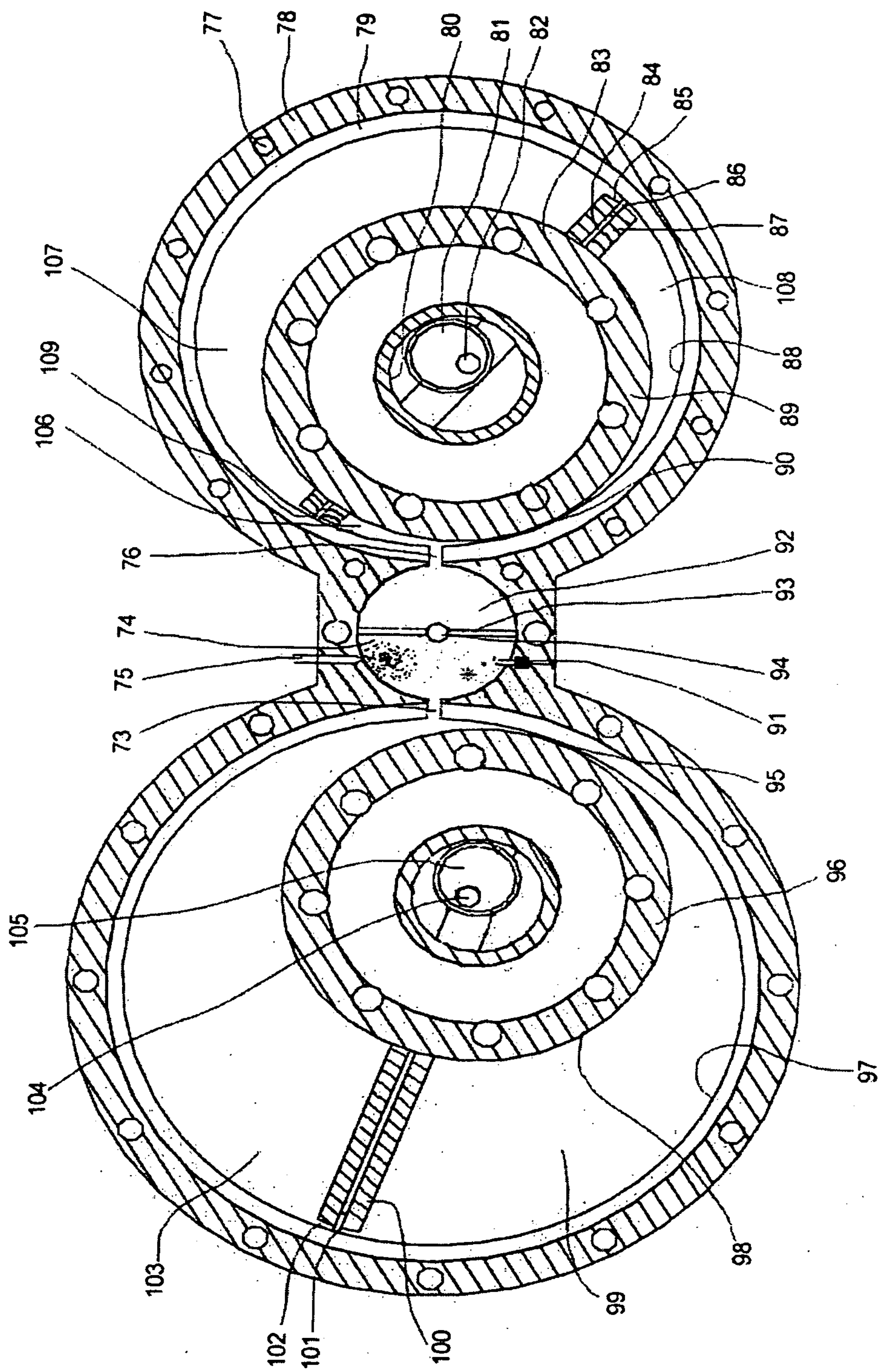

77
78
79
80
81
82
83
84
85
86
87
108
88
89
90
92
93
94
91
95
96
97
98
99
100
101
102
103
104
105
73
75
74
76
106
109
107

FIGURE 3

10/526997

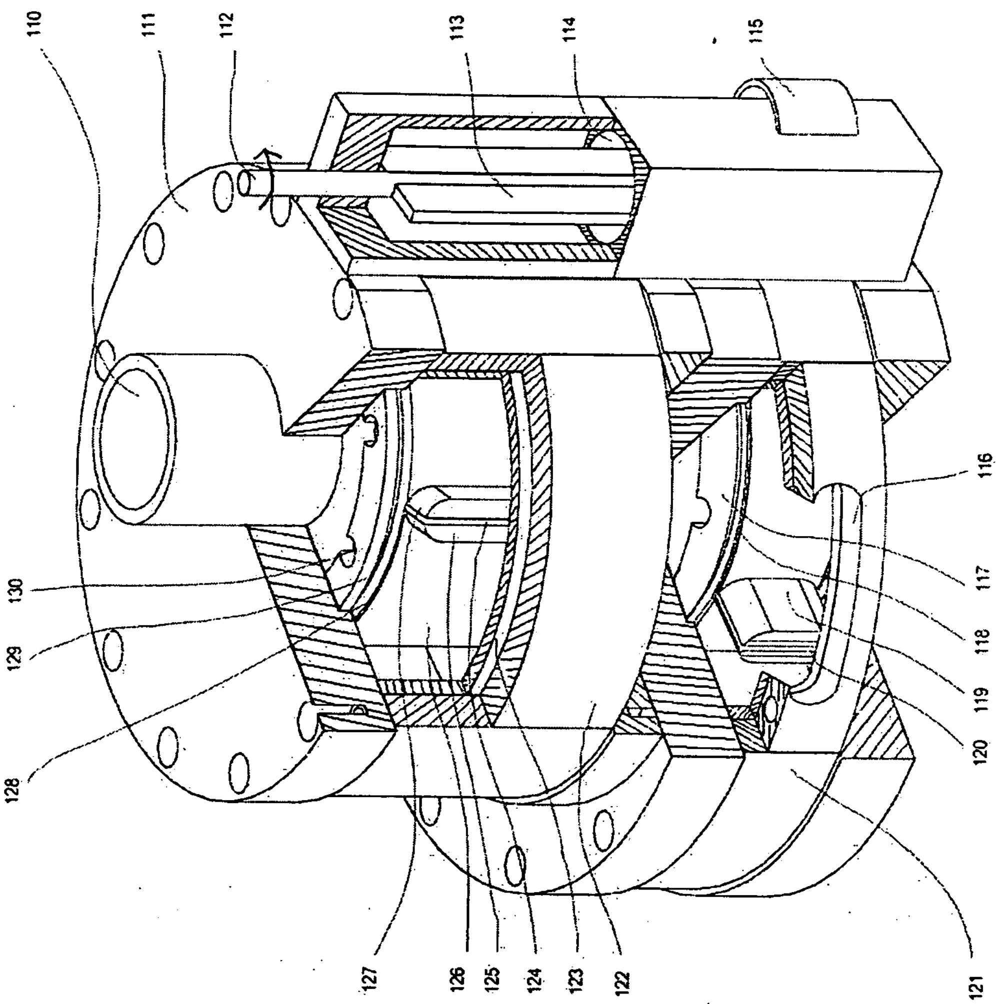


FIGURE 4

10/526997

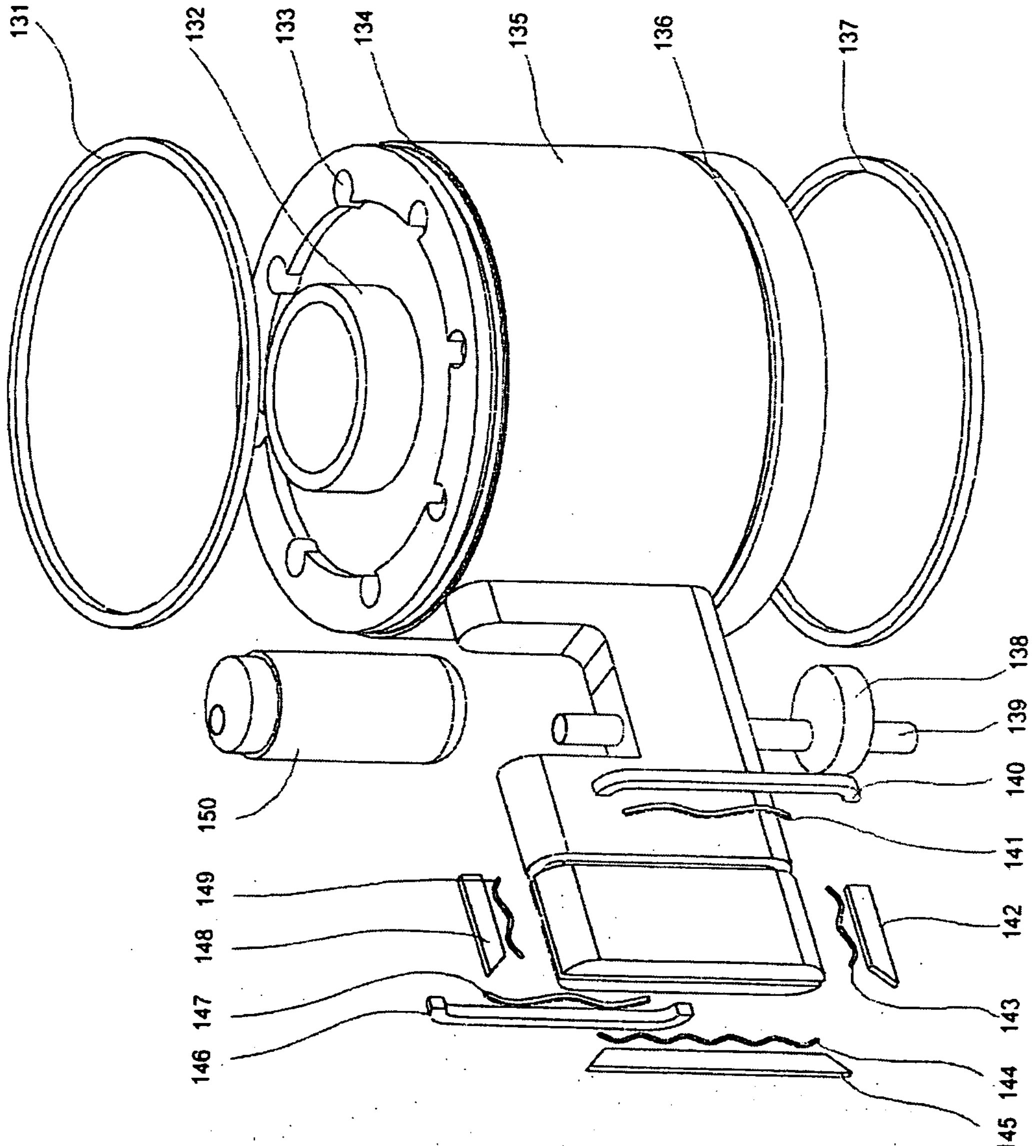


FIGURE 5

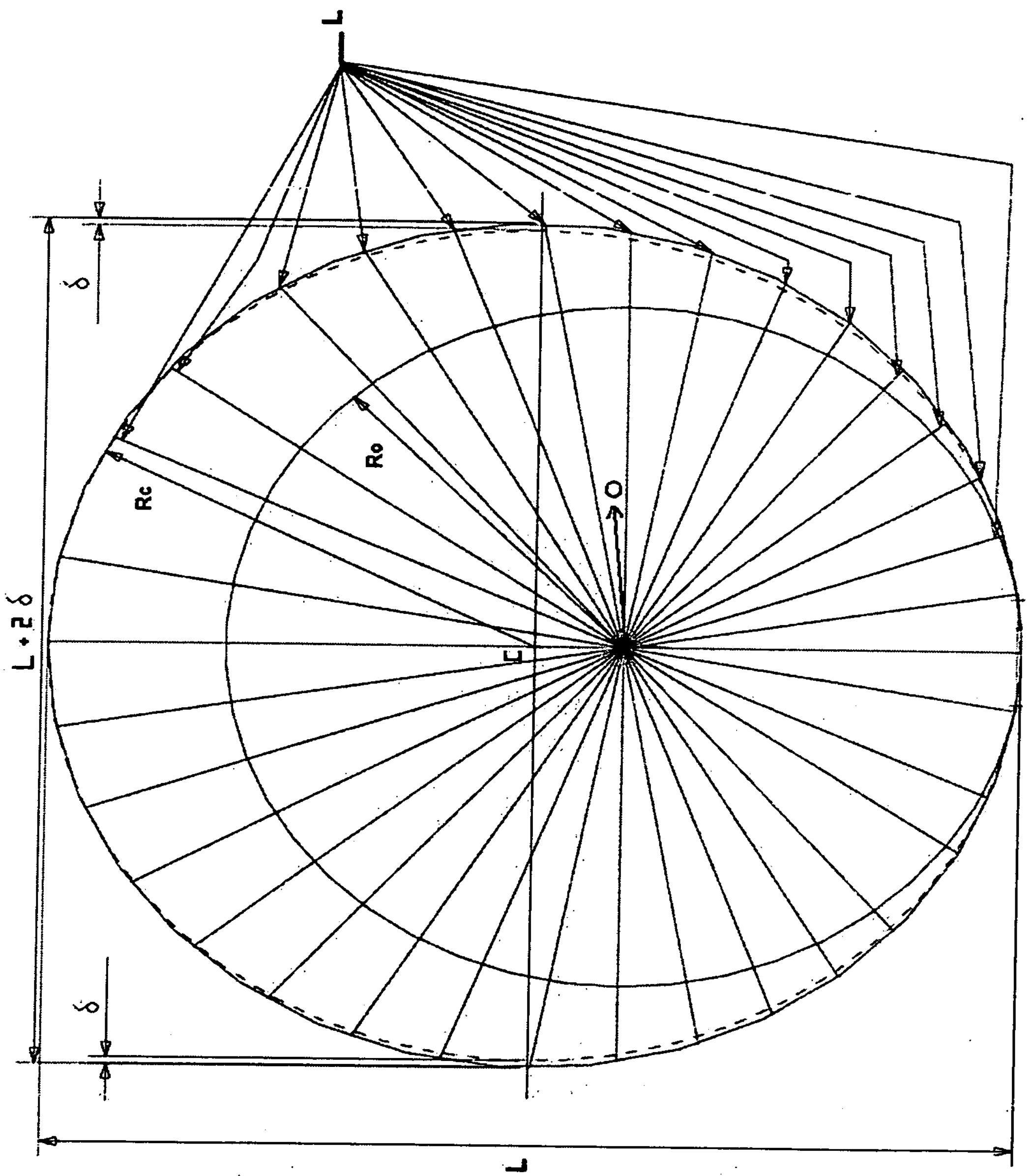


FIGURE 6

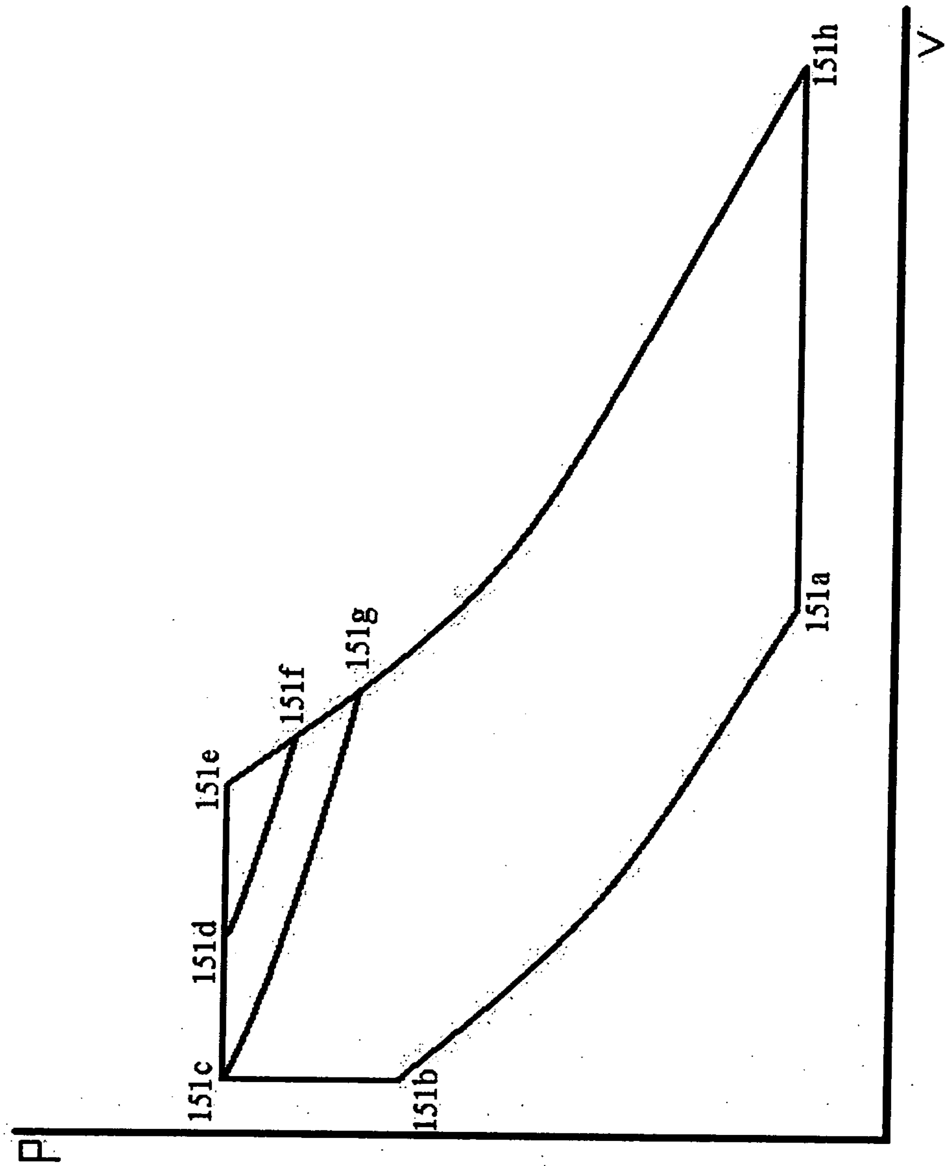
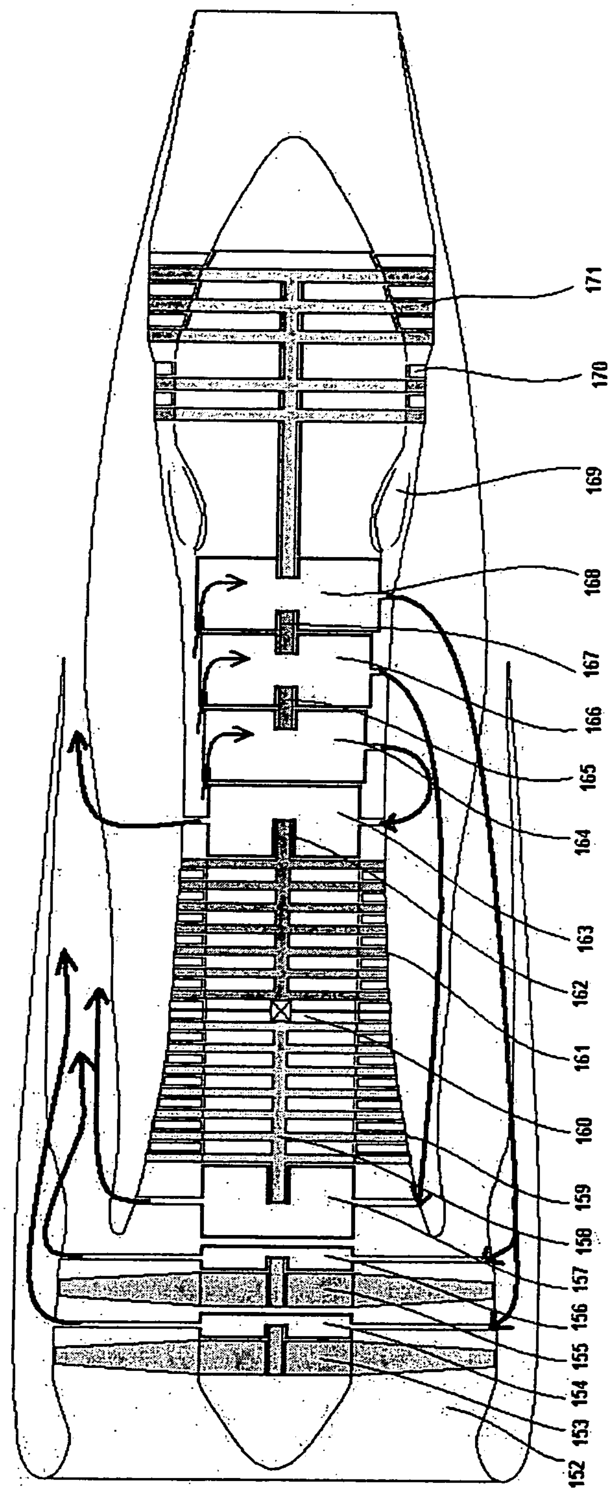


FIGURE 7



171
170
169
168
167
166
165
164
163
162
161
160
159
158
157
156
155
154
153
152

FIGURE 8

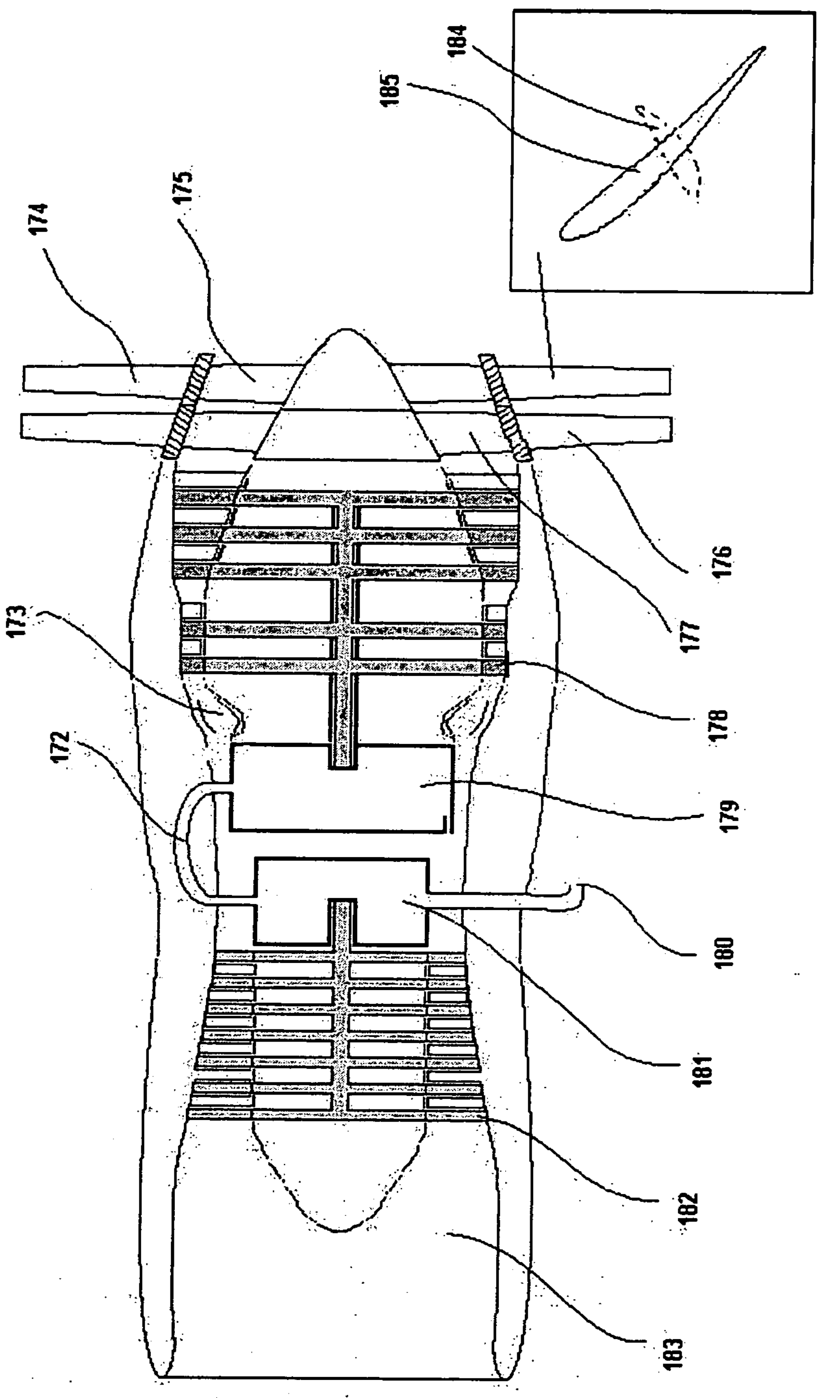


FIGURE 9

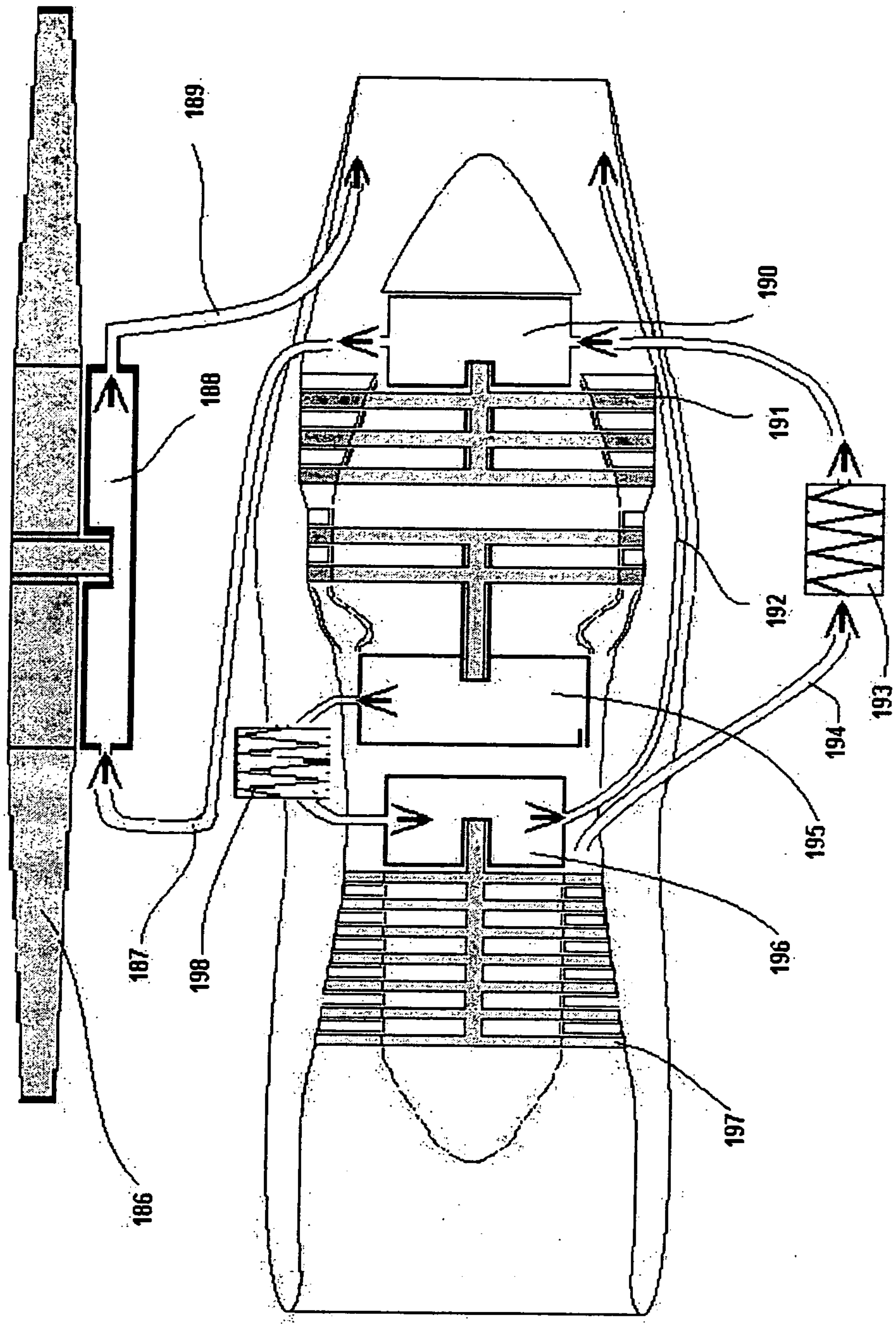


FIGURE 10

INTERNATIONAL SEARCH REPORT

International ication No
PCT/TR 03/00071

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F01C11/00 F01C1/344 F01C21/10 F01C21/08 F01C13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F01C F04C F02C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 016 785 A (SONG JUNYAN) 5 July 2000 (2000-07-05)	1-3,6-8, 10,11, 13,14, 18-20,22
Y	See figures of document WO9853210A (higher quality) figures 1-3,6B,10,11-14 column 6, line 35 -column 7, line 28 column 10, line 15 - line 22 column 12, line 48 -column 13, line 14 column 14, line 44 -column 17, line 5	4,9,21, 23-30, 32-38
Y	US 5 352 295 A (CHOU YI) 4 October 1994 (1994-10-04) cited in the application figure 1	4,9
A	column 4, line 45 - line 65	19,20

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 January 2004	06/02/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Lequeux, F

INTERNATIONAL SEARCH REPORT

International ication No
PCT/TR 03/00071

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 596 963 A (LAI JUI H) 28 January 1997 (1997-01-28) cited in the application figures 1,4 column 3, line 42 - line 50 column 5, line 8 - line 9 column 6, line 18 - line 26 column 7, line 38 - line 48 ---	1,15-20
X	FR 2 539 184 A (BOUDON CHARLES) 13 July 1984 (1984-07-13) figures 1,2,11 page 3, line 29 -page 4, line 19 page 6, line 3 - line 6 page 6, line 33 -page 9, line 6 page 15, line 16 -page 16, line 31 ---	1,15-20
Y A	US 3 900 942 A (AINSWORTH GLENN C) 26 August 1975 (1975-08-26) figures 1-3 column 1, line 45 - line 48 ---	21 2
Y	US 5 566 650 A (KRUSE DOUGLAS C) 22 October 1996 (1996-10-22) cited in the application figures 4A-C,5A-C,8A-C column 2, line 1 - line 18 column 2, line 59 - line 64 column 3, line 21 - line 27 column 11, line 8 - line 41 ---	23-30
X Y	US 5 692 372 A (WHURR JOHN) 2 December 1997 (1997-12-02) figures 1-3 column 2, line 8 - line 38 column 2, line 51 - line 63 column 3, line 17 -column 4, line 15 ---	31 32-38
X	DE 31 28 309 A (SCHMIDT WALTER) 10 February 1983 (1983-02-10) figures 1-3 page 28 -page 29 ---	1,31-34, 37
A	PATENT ABSTRACTS OF JAPAN vol. 004, no. 158 (M-039), 5 November 1980 (1980-11-05) -& JP 55 107002 A (KIMURA SHIGEYUKI), 16 August 1980 (1980-08-16) abstract figures 1,4,20,23 ---	5,12
A	GB 697 078 A (ROBERT DESMOND PARKER) 16 September 1953 (1953-09-16) figures 1-4 --- -/--	5,12

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	FR 538 666 A (KITSON ARTHUR;UTLEY EMILY) 13 June 1922 (1922-06-13) figures 1-3 page 1, line 1 - line 25 page 2, line 87 -page 3, line 15	2,21
A	US 6 236 897 B1 (PARK YONG HEE ET AL) 22 May 2001 (2001-05-22) cited in the application figures 3,4 column 4, line 33 - line 53 claim 1	18,19,21
A	WO 98 53210 A (SONG JUNYAN) 26 November 1998 (1998-11-26) Family of EP1016785, this document is cited due to the higher quality of the figures	1

Internati[...] application No.
PCT/TR 03/00071

INTERNATIONAL SEARCH REPORT

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1,2-4,6-11,13,20,21

   Sliding vane rotary engine with cycloidal inner surfaces of the chambers

2. Claims: 1,2,5,7,12

   Sliding vane rotary engine with retention mechanism for the vane

3. Claims: 1,14,15

   Sliding vane rotary engine with coupling mechanisms

4. Claims: 1,16,17

   Sliding vane rotary engine with valve structures

5. Claims: 1,18

   Sliding vane rotary engine with injection system

6. Claims: 1,19

   Sliding vane rotary engine with cooling means

7. Claims: 1,22-30

   Method of operating a sliding vane rotary engine and specific thermodynamic cycles

8. Claims: 1,31-38

   Sliding vane rotary engine with specific driving/driven means

INTERNATIONAL SEARCH REPORT

Infor........ on patent family members

International cation No
PCT/TR 03/00071

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 1016785	A	05-07-2000	AU	7519198	A	11-12-1998
			EP	1016785	A1	05-07-2000
			WO	9853210	A1	26-11-1998
			CN	1255186	T	31-05-2000
US 5352295	A	04-10-1994	CN	1066318	A	18-11-1992
			JP	6093872	A	05-04-1994
US 5596963	A	28-01-1997	NONE			
FR 2539184	A	13-07-1984	FR	2539184	A1	13-07-1984
US 3900942	A	26-08-1975	NONE			
US 5566650	A	22-10-1996	US	5460128	A	24-10-1995
			US	5265562	A	30-11-1993
			US	2001050068	A1	13-12-2001
			US	6058904	A	09-05-2000
			AU	4785193	A	14-02-1994
			DE	69327653	D1	24-02-2000
			DE	69327653	T2	31-08-2000
			EP	0653018	A1	17-05-1995
			JP	8500166	T	09-01-1996
			WO	9402726	A1	03-02-1994
US 5692372	A	02-12-1997	GB	2301632	A ,B	11-12-1996
			DE	19600679	A1	19-09-1996
DE 3128309	A	10-02-1983	DE	3300761	A1	12-07-1984
			DE	3128309	A1	10-02-1983
JP 55107002	A	16-08-1980	NONE			
GB 697078	A	16-09-1953	NONE			
FR 538666	A	13-06-1922	NONE			
US 6236897	B1	22-05-2001	KR	173342	B1	18-02-1999
			AU	6533096	A	26-02-1997
			CN	1197503	A	28-10-1998
			EP	0842364	A1	20-05-1998
			JP	11512163	T	19-10-1999
			WO	9705391	A1	13-02-1997
WO 9853210	A	26-11-1998	AU	7519198	A	11-12-1998
			WO	9853210	A1	26-11-1998
			CN	1255186	T	31-05-2000
			EP	1016785	A1	05-07-2000